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Umeda

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(54) **INK-JET PRINTER**

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(73) Assignee: **Brother Kogyo Kabushiki Kaisha**, Nagoya-shi, Aichi-ken (JP)

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May 28, 2007 (JP) 2007-140536

(51) **Int. Cl.**
B41J 2/175 (2006.01)

(52) **U.S. Cl.** **347/85**; 347/65; 347/66; 347/84; 347/86; 347/87; 347/88; 347/89; 347/90; 347/91; 347/92; 347/93; 347/94

(58) **Field of Classification Search** 347/65–66, 347/84–94

See application file for complete search history.

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(57) **ABSTRACT**

An ink-jet printer, including: a recording head which ejects ink onto a recording medium; a main tank which stores the ink to be supplied to the recording head; a sub tank configured to be extended and contracted in a vertical direction and including first and second ink flow holes provided in a lower portion of the sub tank, such that the first ink flow hole communicates with the recording head while the second ink flow hole communicates with the main tank; and a communication tube which is connected, at one of opposite ends thereof, to the second ink flow hole and which has, at the other of opposite ends thereof, an opening positioned in an inside space of the sub tank, whereby the second ink flow hole and the inside space of the sub tank communicate with each other via the communication tube, wherein the communication tube is configured such that the opening of the communication tube is displaced downwardly in accordance with the contraction of the sub tank.

14 Claims, 6 Drawing Sheets

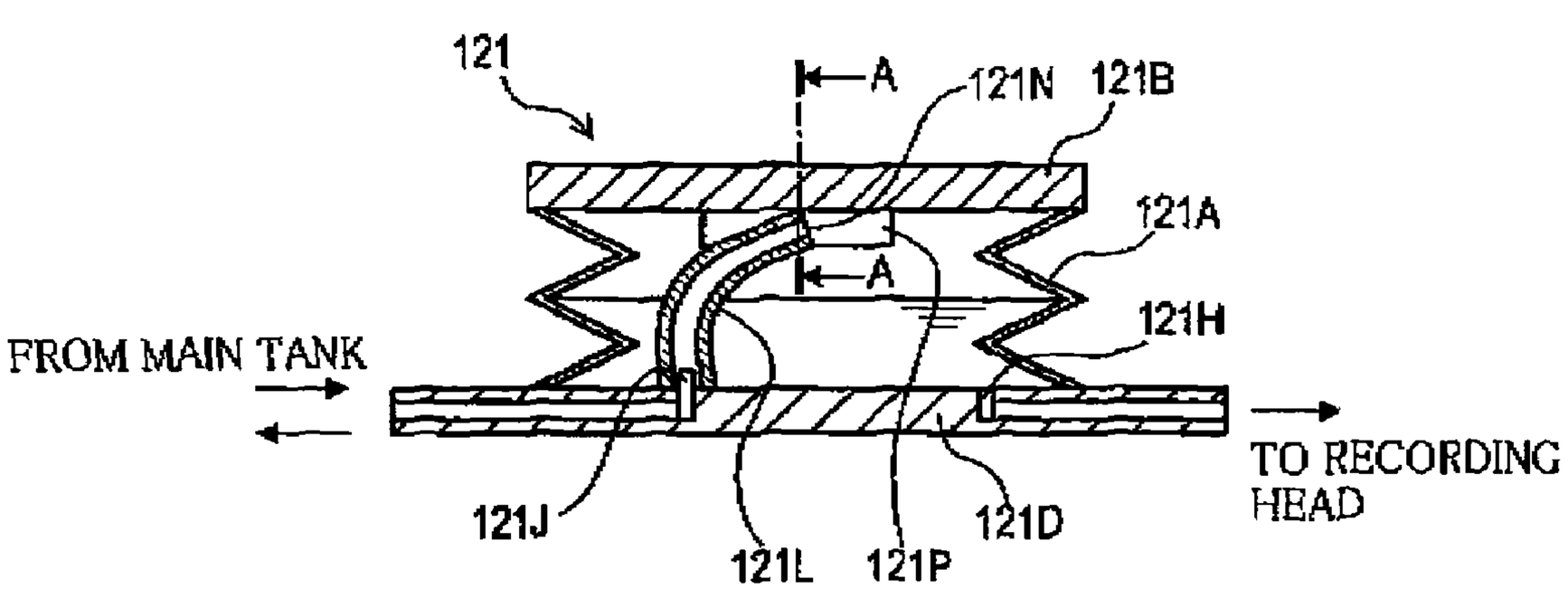


FIG. 1

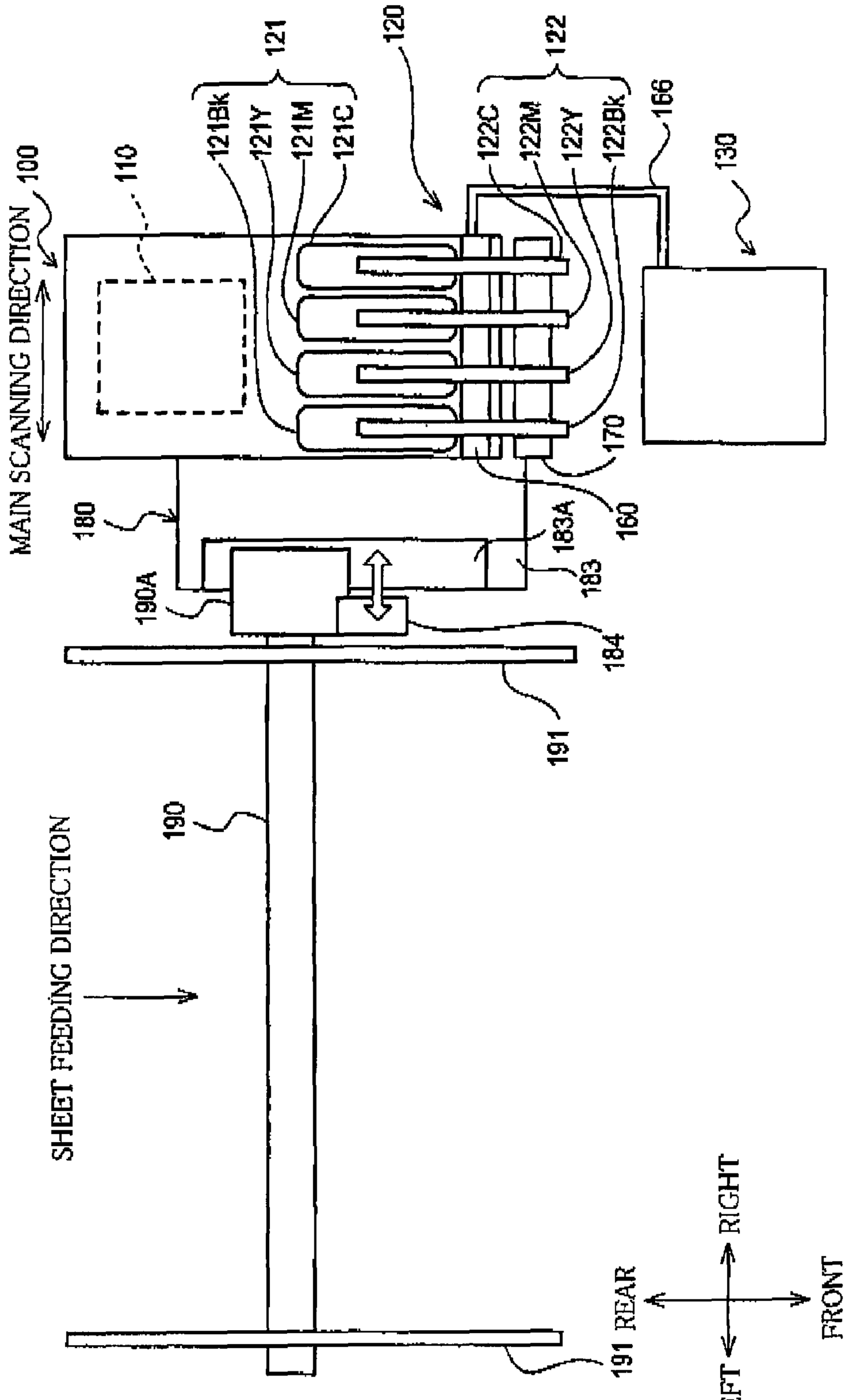

100
110
121
121Bk
121Y
121M
121C
120
122
122C
122M
122Y
122Bk
166
130
170
160
180
183A
183
190A
184
191
190
MAIN SCANNING DIRECTION
SHEET FEEDING DIRECTION
191 REAR
LEFT
RIGHT
FRONT

FIG.2A

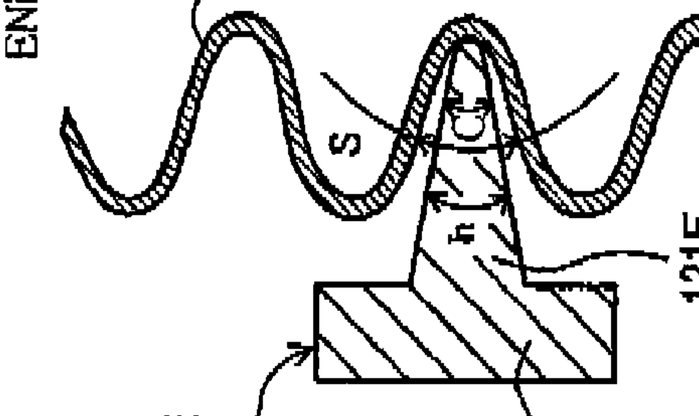


FIG.2B

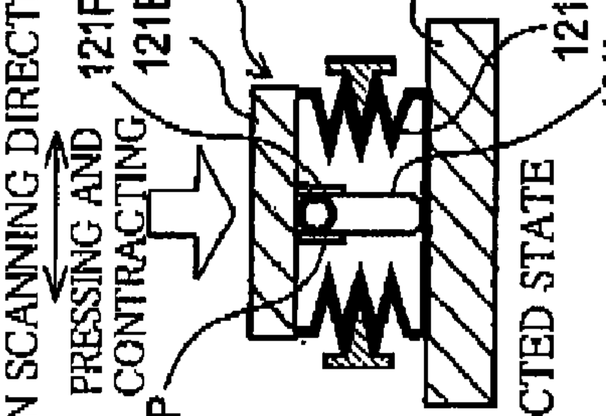


FIG.2C

FIG.2D

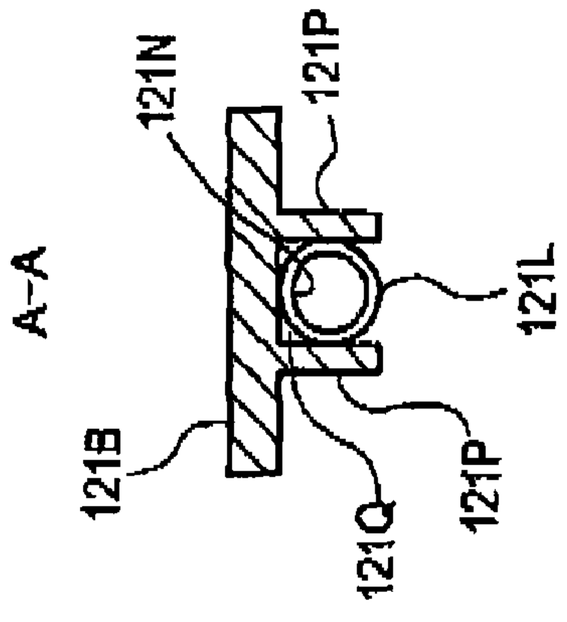
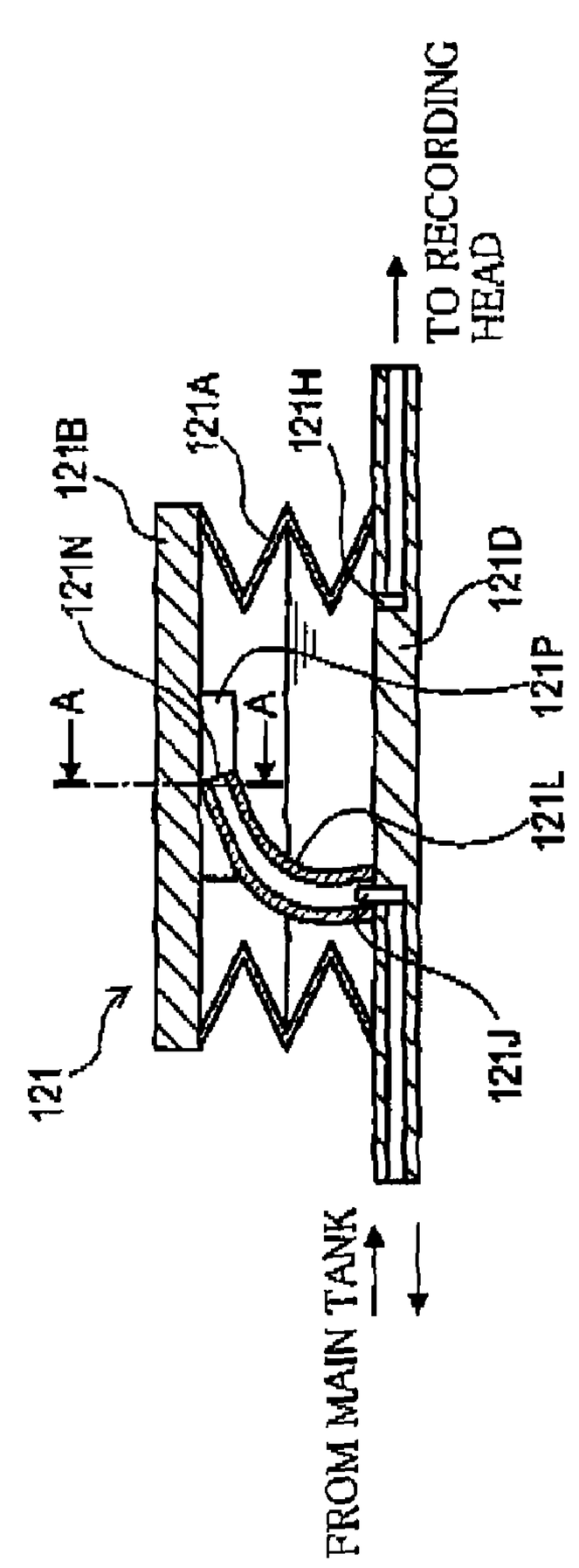


FIG.3B

FIG.3A



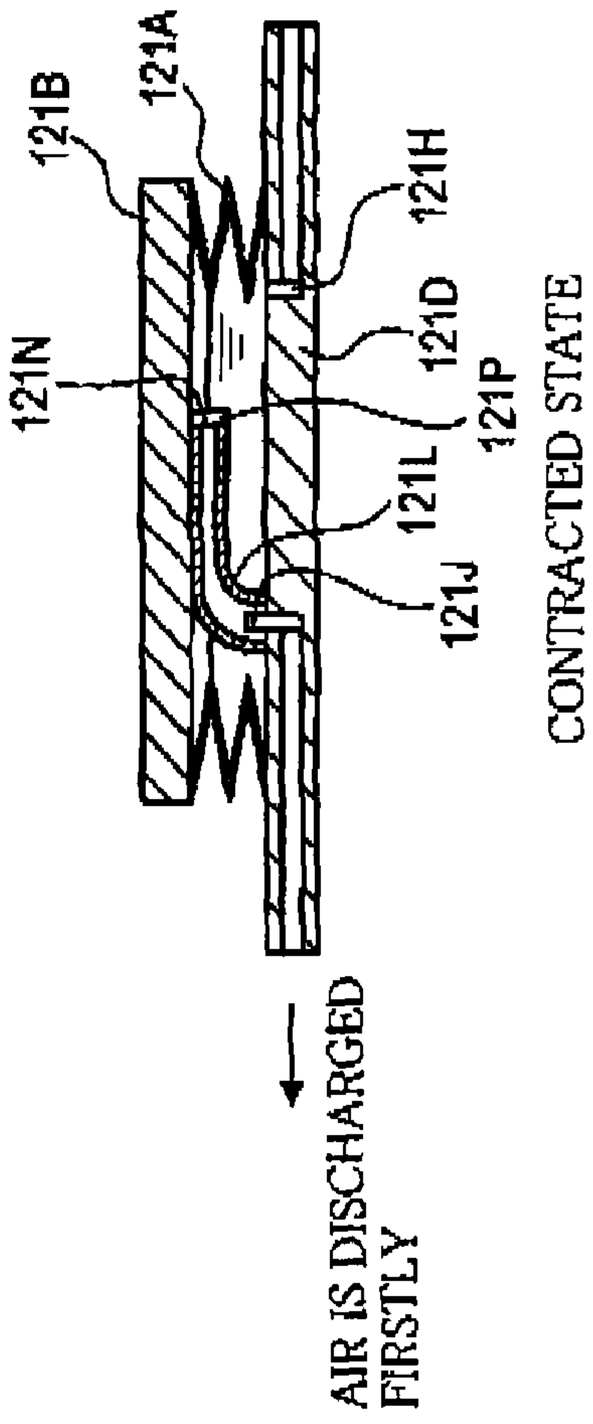


FIG.3C

FIG. 4B

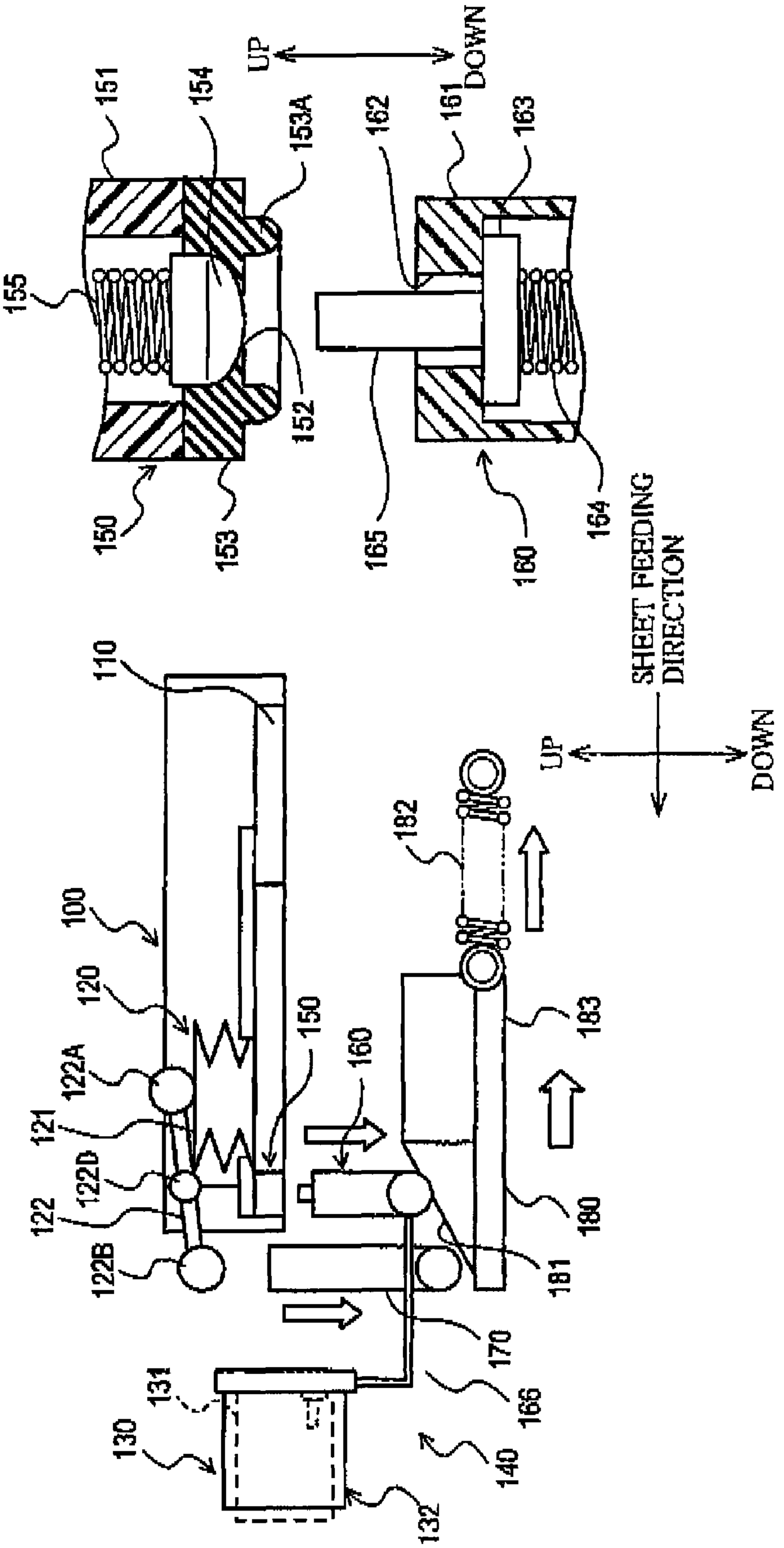
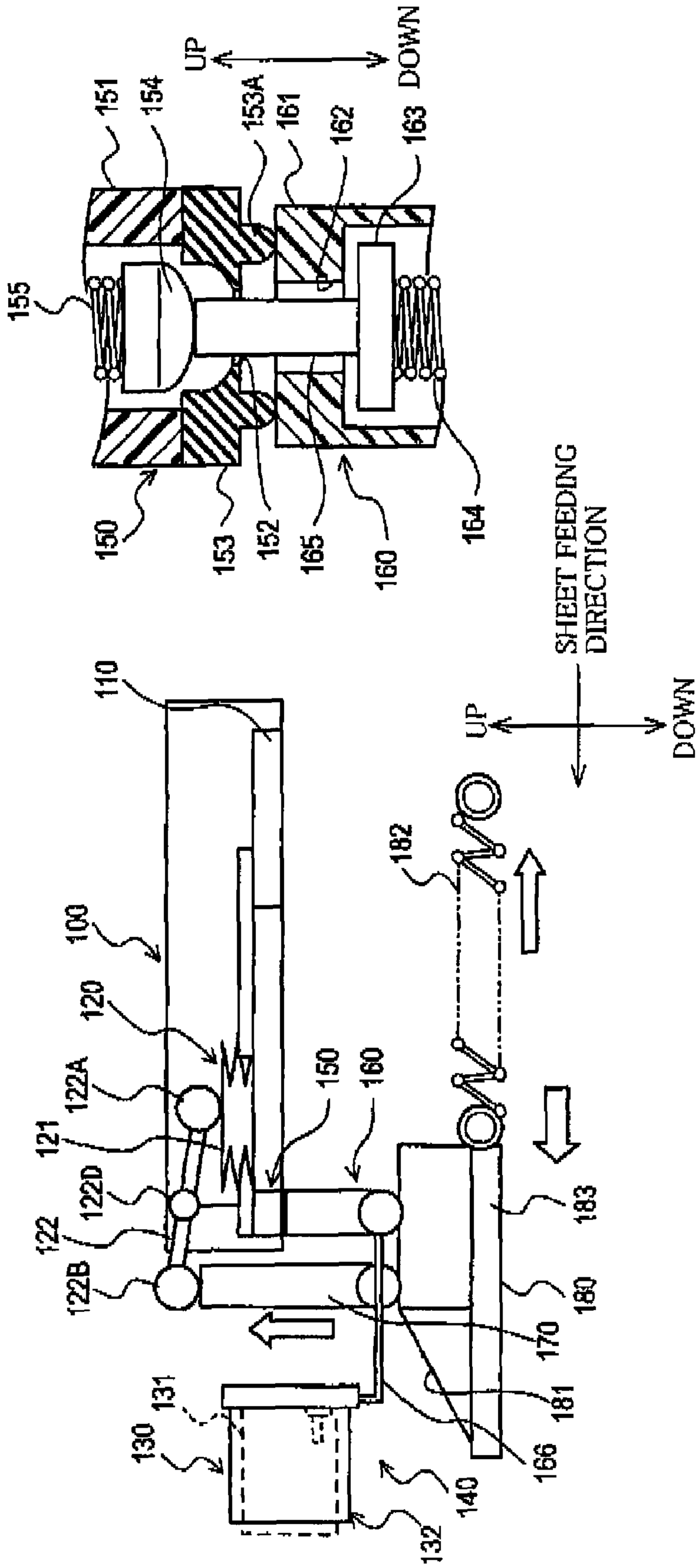

UP
DOWN
151
154
153A
162
161
163
155
152
150
153
165
160
164
SHEET FEEDING DIRECTION
UP
DOWN
110
100
120
150
160
182
183
122A
121
122D
122
122B
180
181
170
131
130
166
140
132

FIG. 4A

FIG.5B


UP
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SHEET FEEDING DIRECTION
UP
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182
110
100
120
122A
121
122D
122
122B
150
160
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180
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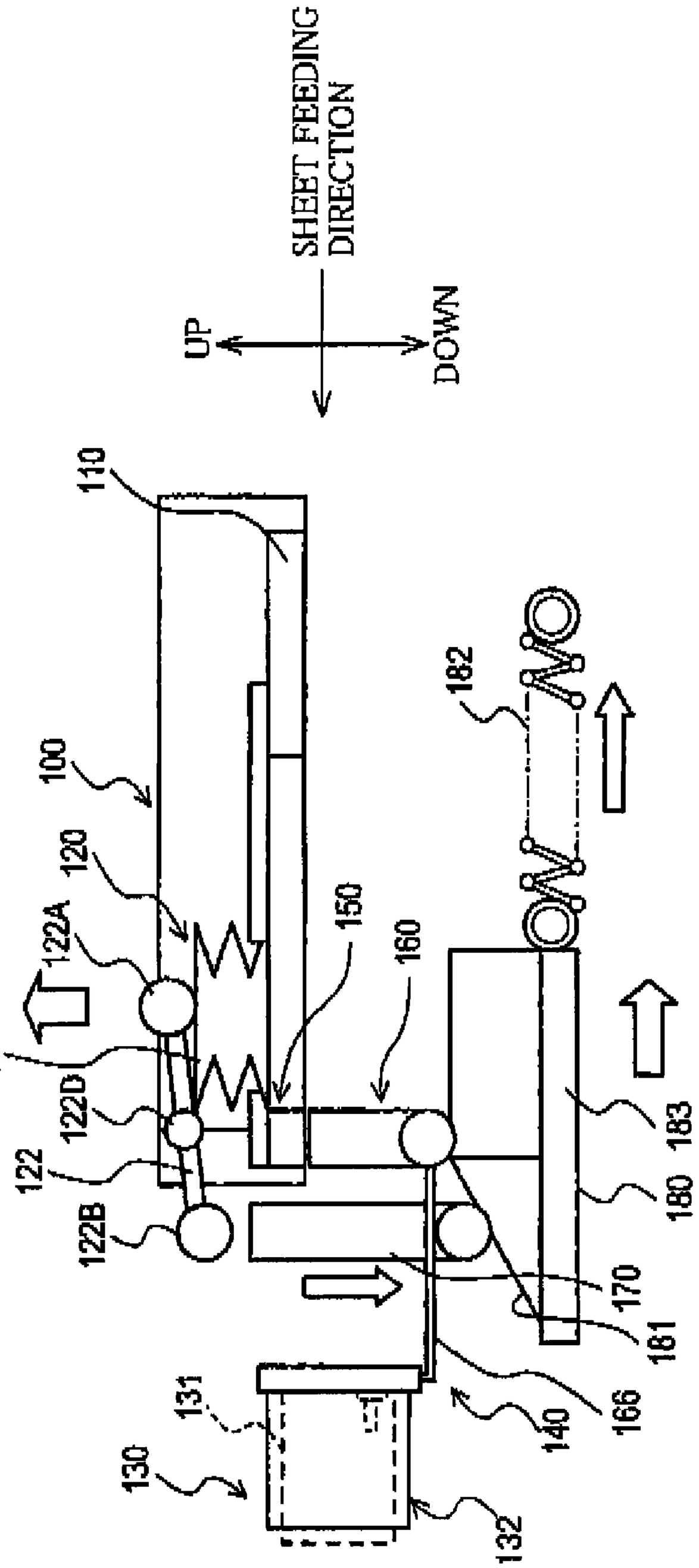
181
166
131
130
140
132

FIG.5A

FIG.6


SHEET FEEDING DIRECTION
UP
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INK-JET PRINTER

CROSS REFERENCE TO RELATED APPLICATION

The present application claims priority from Japanese Patent Application No. 2007-140536, which was filed on May 28, 2007, the disclosure of which is herein incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an ink-jet printer including sub tanks which can be extended and contracted.

2. Description of the Related Art

Patent Document 1 (Japanese Patent Application Publication No. 2004-358918) discloses an ink-jet printer including extendable and contractable sub tanks provided in a path leading ink from a main tank to a recording head. The ink is temporarily accommodated in the sub tanks, thereby evening an ink pressure which is variable according to a remaining amount of the ink in the main tank.

SUMMARY OF THE INVENTION

However, in the ink-jet printer disclosed in the Patent Document 1, first ink flow holes communicating with the recording head are respectively provided in upper portions of the respective sub tanks, and second ink flow holes communicating with the main tank are respectively provided in lower portions of the respective sub tanks. Thus, where the sub tanks are contracted in order to discharge air in the sub tanks to the main tank, air accumulated in upper end portions of inside spaces of the respective sub tanks is supplied to the recording head, and only the ink existing in lower portions of inside spaces of the respective sub tanks is supplied to the main tank. Thus, ink ejection failure easily occurs in comparison with an ink-jet printer not having a configuration like this.

This invention has been developed in view of the above-described situation, and it is an object of the present invention to provide an ink-jet printer in which air in the sub tanks can be reliably discharged to the main tank.

The object indicated above may be achieved according to the present invention which provides an ink-jet printer comprising: a recording head which ejects ink onto a recording medium; a main tank which stores the ink to be supplied to the recording head; a sub tank configured to be extended and contracted in a vertical direction and including first and second ink flow holes provided in a lower portion of the sub tank, such that the first ink flow hole communicates with the recording head while the second ink flow hole communicates with the main tank; and a communication tube which is connected, at one of opposite ends thereof, to the second ink flow hole and which has, at the other of opposite ends thereof, an opening positioned in an inside space of the sub tank, whereby the second ink flow hole and the inside space of the sub tank communicate with each other via the communication tube, wherein the communication tube is configured such that the opening of the communication tube is displaced downwardly in accordance with the contraction of the sub tank.

In the ink-jet printer constructed as described above, the second ink flow hole and the inside space of the sub tank communicate with each other via the opening which is displaced downwardly in accordance with the contraction of the sub tank. Further, air in the sub tank is always positioned in an upper portion of the inside space of the sub tank irrespective of a degree of a contraction of the sub tank.

Thus, the ink-jet printer according to the present invention can be configured such that the opening is positioned, irrespective of the degree of the deformation of the sub tank, at a part of the inside space of the sub tank in which air is accumulated. Where the ink-jet printer is thus configured, the air in the sub tank can be reliably discharged to the main tank.

BRIEF DESCRIPTION OF THE DRAWINGS

The objects, features, advantages, and technical and industrial significance of the present invention will be better understood by reading the following detailed description of preferred embodiments of the invention, when considered in connection with the accompanying drawings, in which:

FIG. **1** is a schematic view of an image forming section of an ink-jet printer as the present embodiment as seen from an upper side of the ink-jet printer;

FIG. **2**A is an elevational view of one of deformation restraining rings **121**E, FIGS. **2**B and **2**C are views each showing a state in which one of the deformation restraining rings **121**E is fitted on a corresponding one of sub tanks **121**, and FIG. **2**D is an enlarged view of an area A in FIG. **2**B;

FIGS. **3**A and **3**C are cross-sectional views of one of the sub tanks **121**, and FIG. **3**B is a cross-sectional view showing a cross section of FIG. **3**A taken along a line A-A;

FIG. **4**A is a view for explaining an operation of supplying ink, and FIG. **4**B is a view for explaining an operation of a joint valve upon the operation of supplying ink;

FIG. **5**A is a view for explaining the operation of supplying ink, FIG. **5**B is a view for explaining the operation of the joint valve upon the operation of supplying ink; and

FIG. **6** is a view for explaining the operation of supplying ink.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the present embodiment, an, ink-jet printer according to the present invention is applied to an ink-jet printer of a station supply type. Hereinafter, there will be described, by reference to the drawings, the ink-jet printer of the station supply type as the present embodiment according to the present invention.

1. Summary of Ink-Jet Printer as the Present Embodiment

The ink-jet printer, as is well known, forms an image on a recording medium such as a recording sheet by ejecting fine ink droplets onto the sheet. When forming a color image, the ink-jet printer ejects ink of various colors different from each other, e.g., cyan, magenta, yellow, and black, such that the different-color inks are overlaid on one another.

Also, in the ink-jet printer of the station supply type, the main tank unit **130** and the sub tanks **121** that will be described below are connected to each other when the ink is supplied to the sub tanks **121**, whereas the main tank unit **130** and the sub tanks **121** are not connected to each other when the ink is not supplied to the sub tanks **121**, for example, when the image is being formed.

In this ink-jet printer, when a remaining amount of the ink in the sub tanks **121** is equal to or smaller than a certain amount, the main tank unit **130** and the sub tanks **121** are connected to each other to refill the sub tanks **121** with the ink. On the other hand, when the remaining amount of the ink in the sub tanks **121** is larger than the certain amount, the main tank unit **130** and the sub tanks **121** are not connected to each other.

2. Recording Head Unit

In FIG. **1**, a recording head unit **100** includes a recording head **110** for ejecting the ink droplets onto the sheet, a sub tank unit **120** for supplying the ink to the recording head **110**, and so on. The recording head **110**, the sub tank unit **120**, and so on are mounted on a carriage (not shown). When the image is being formed, this recording head unit **100** is reciprocated in a direction that is perpendicular to a sheet feeding direction in which the sheet is fed and that is a direction parallel to one of opposite surfaces of the sheet on which the image is to be recorded. That is, the recording head unit **100** is reciprocated in a lateral direction in FIG. **1** (i.e., a main scanning direction).

It is noted that a plurality of nozzles (not shown) through which the ink is ejected are formed for each of the colors in one of faces of the recording head **110** which faces a fed sheet. These nozzles are arranged in a row or rows for each color in a direction parallel to the sheet feeding direction.

The sub tank unit **120** includes a plurality of the sub tanks **121**C, **121**M, **121**Y, **121**Bk which are aligned in the main scanning direction, pressing levers **122**C, **122**M, **122**Y, **122**Bk respectively for pressing the sub tanks **121**C, **121**M, **121**Y, **121**Bk, and so on.

In this respect, cyan (C) ink, magenta (M) ink, yellow (Y) ink, and black (Bk) ink are respectively stored in the sub tanks **121**C, **121**M, **121**Y, **121**Bk.

It is noted that since respective constructions of the sub tanks **121**C, **121**M, **121**Y, **121**Bk are identical with each other except for the type of the ink stored therein, hereinafter these sub tanks will be collectively referred to as sub tanks **121**. Similarly, since the pressing levers **122**C, **122**M, **122**Y, **122**Bk are identical with each other except for the sub tanks **121** to be pressed thereby, hereinafter these pressing levers will be collectively referred to as pressing levers **122**.

Further, as shown in FIG. **4**A, described for one of the pressing levers **122** for simplicity, the pressing lever **122** functioning as a pressing means is pivotably engaged at its one end **122**A with an upper end portion of the sub tank **121**. On the other hand, the other end **122**B of the pressing lever **122** extends to an outside of an outer edge portion of the recording head unit **100**. Between the one end **122**A and the other end **122**B in a longitudinal direction of the pressing lever **122**, the pressing lever **122** is supported at a supported portion **122**D thereof so as to be pivotable. It is noted that the supported portion **122**D is provided on a main body of the recording head unit **100**.

3. Sub Tanks

Described for one of the sub tanks **121** for simplicity, the sub tank **121** is configured to be deformed so as to be elastically extended and contracted in a direction perpendicular to the main scanning direction and the sheet feeding direction (hereinafter, the direction may be referred to as an extension and contraction direction). In this ink-jet printer, the sub tank **121** is deformed in a vertical direction. More specifically, as shown in, e.g., FIGS. **2**B and **3**A, the sub tank **121** includes a bellows portion **121**A as a peripheral wall configured to be deformed so as to be extended and contracted in the vertical direction, a top plate portion **121**B as an upper end wall which closes the bellows portion **121**A from an upper side thereof, a bottom plate portion **121**D as a lower end wall which closes the bellows portion **121**A from a lower side thereof, and so on. In this respect, FIG. **2**B shows a normal state of the sub tank **121** in which the sub tank **121** is extended, and FIG. **2**C shows a state of the sub tank **121** in which the sub tank **121** is contracted.

It is noted that the extension and contraction direction of the sub tank **121** does not need to strictly coincide with a direction in which a vertical line extends, and may be displaced about 45 degrees with respect to the vertical line. As shown in FIG. **1**, the sub tank **121** has a rectangular shape with its corners smoothly rounded in cross section in a plane perpendicular to the extension and contraction direction of the bellows portion **121**A. It is noted that, in this ink-jet printer, longer sides of the sub tank **121** are parallel to the sheet feeding direction, and shorter sides thereof are parallel to the main scanning direction. Further, the plurality of the sub tanks **121** are aligned in the main scanning direction.

Further, the bellows portion **121**A has a bellows shape and formed of a material with an excellent toughness such as a polypropylene (PP), a polyethylene (PE), or an elastomeric material. As shown in FIG. **2**B, on an outer side of the bellows portion **121**A, there is fitted a deformation restraining ring **121**E as a deformation restraining member which restrains the sub tank **121** (i.e., the bellows portion **121**A) from deforming in a direction intersecting the extension and contraction direction thereof (in this ink-jet printer, in the main scanning direction and a sub scanning direction).

As shown in FIG. **2**A, the deformation restraining ring **121**E has a generally rectangular shape having rounded corners in cross-sectional shape of the bellows portion **121**A. Further, as shown in FIG. **2**D, this deformation restraining ring **121**E includes a contacting portion **121**F contacting the outer side of the bellows portion **121**A, and a reinforcing portion **121**G which reinforces the contacting portion **121**F at a position opposed to the bellows portion **121**A with the contacting portion **121**F interposed therebetween.

It is noted that, in this ink-jet printer, the contacting portion **121**F and the reinforcing portion **121**G are each formed of a resin material having an excellent mechanical strength such as a polyacetal and are integral with each other. Further, as shown in FIG. **2**B, in a state in which the contacting portion **121**F is fitted on one of smaller diameter parts of the bellows portion **121**A, the deformation restraining ring **121**E is fitted on the outer side of the bellows portion **121**A at a position at which to divide the bellows portion **121**A into equal parts (in this ink-jet printer, two parts) in the extension and contraction direction of the bellows portion **121**A.

Here, the position at which to divide the bellows portion **121**A into equal parts in the extension and contraction direction is not limited to a position at which to strictly divide the bellows portion **121**A into equal parts. Depending on a number of the smaller diameter parts and a size of each of the smaller diameter parts, the position at which to divide the bellows portion **121**A into equal parts may be out of the position in which to strictly divide the bellows portion **121**A into equal parts. That is, the position in which to divide the bellows portion **121**A into equal parts in the extension and contraction direction means a position which can be visually recognized, by persons skilled in the art not using any measuring instrument such as a vernier caliper, to be a position in which to divide the bellows portion **121**A into equal parts in the extension and contraction direction.

As shown in FIG. **2**D, the contacting portion **121**F has a taper shape (i.e., a triangle shape). That is, a dimension h of the contacting portion **121**F in a direction parallel to the extension and contraction direction decreases as being nearer to the bellows portion **121**A. An angle C of the contacting portion **121**F is set to be equal to or smaller than an angle S of each smaller diameter part in a state in which the bellows portion **121**A is contracted to the greatest extent.

Each of the top plate portion **121**B and the bottom plate portion **121**D has a material or a shape in which each of the top plate portion **121**B and the bottom plate portion **121**D has a flexural rigidity higher than that of the bellows portion **121**A such that the top plate portion **121**B and the bottom plate

portion **121**D are not to be bent or deformed when the top plate portion **121**B is pressed by the pressing lever **122**.

As shown in FIG. **3**A, in the bottom plate portion **121**D, there are formed a first ink flow hole **121**H which communicates with the recording head **110**, and a second ink flow hole **121**J which communicates with the main tank unit **130**. This second ink flow hole **121**J and an upper end portion of an inside space of the sub tank **121** (i.e., a space near the top plate portion **121**B) communicate with each other via a communication tube **121**L. The entirety of the communication tube **121**L is in the sub tank **121**.

More specifically, the communication tube **121**L is connected, at one of opposite ends thereof, to the second ink flow hole **121**J from the inside space of the sub tank **121**, and has, at the other of the opposite ends thereof an opening **121**N that is open at the upper end portion of the inside space of the sub tank **121**. That is, the communication tube **121**L extends from the bottom plate portion **121**D toward the top plate portion **121**B. Also, in a state in which the sub tank **121** is extended, the opposite ends of the communication tube **121**L are positioned at respective positions each of which is located outside a central part of the top plate portion **121**B as seen from the upper side of the sub tank. It is noted that, in FIG. **3**, the deformation restraining ring **121**E is omitted due to limitations of space. Also, the respective sub tanks shown in FIGS. **2** and **3** are simplified in shape.

The communication tube **121**L is a circular tube formed of a material, such as an elastomer, which can be elastically deformed in accordance with the extension and contraction of the sub tank **121**. The communication tube **121**L is bent in a state in which an upper end portion (at which the opening **121**N is formed) of the communication tube **121**L directly or indirectly contacts the top plate portion **121**B even when a vertical dimension of the sub tank **121** (the bellows portion **121**A) is maximized as a result of the extension of the sub tank **121**. In other words, the communication tube **121**L constantly contacts, at the other of the opposite ends thereof, the top plate portion **121**B irrespective of a degree of the extension and contraction of the sub tank **121**. Thus, the top plate portion **121**B and the bottom plate portion **121**D are forced by an elastic restoration force generated by the communication tube **121**L, so as to be displaced away from each other.

Thus, the communication tube **121**L is bent or deformed more strongly, in accordance with the contraction of the sub tank **121**, by the pressing lever **122** pressing the top plate portion **121**B. Consequently, the opening **121**N is displaced downwardly in accordance with the contraction of the sub tank **121**.

In contrast, when the pressing lever **122** is released, that is, a pressing force generated by the pressing lever **122** is removed, the opening **121**N is upwardly displaced by a restoration force of the sub tank **121** and a restoration force of the communication tube **121**L in accordance with the extension of the sub tank **121**. That is, in this ink-jet printer, the opening **121**N is constantly positioned at the upper end portion of the inside space of the sub tank **121** irrespective of the degree of the extension and contraction of the sub tank **121**.

The sub tank **121** includes a guide which guides the communication tube **121**L. As shown in FIGS. **3**A and **3**B, the guide is constituted by two deformation guiding ribs **121**P provided on a lower face of the top plate portion **121**B and each functioning as a deformation guiding member which guides the communication tube **121**L such that the opening **121**N moves, in accordance with the contraction of the sub tank **121**, toward the central part of the top plate portion **121**B as seen from an upper side of the top plate portion **121**B.

As shown in FIG. **3**A, the deformation guiding ribs **121**P are a pair of wall-like members each extending toward the central part of the top plate portion **121**B from a part of the top plate portion **121**B which is located at a position just above a position at which the communication tube **121**L and the second ink flow hole **121**J are connected to each other. As shown in FIG. **3**B, the other of the opposite ends (i.e., the upper end portion of the communication tube **121**L) and part of the communication tube **121**L is slidably received in a groove portion **121**Q which is defined by the pair of the deformation guiding ribs **121**P and the top plate portion **121**B so as to have a generally rectangular three-sided shape. That is, the deformation guiding ribs **121**P are configured to guide the communication tube **121**L in a state in which the deformation guiding ribs **121**P engage opposite sides of the other of the opposite ends of the communication tube **121**L, which opposite sides are radially opposed to each other in the direction perpendicular to the vertical direction. As a result, the deformation guiding ribs **121**P guide the communication tube **121**L such that the opening **121**N is moved in one direction as seen from the upper side of the sub tank **121**.

Here, the central part of the top plate portion **121**B is generally located at a position of the top plate portion **121**B at which moments acting on the top plate portion **121**B are generally in balance. The moments acting on the top plate portion **121**B includes a moment produced by a force of the bellows portion **121**A which acts on the top plate portion **121**B, a moment produced by a pressure in the sub tank **121** which acts on the top plate portion **121**B, and the like.

It is noted that, in this ink-jet printer, since the bellows portion **121**A can be considered to apply a force to the top plate portion **121**B approximately evenly, and an internal pressure evenly applies to an entirety of the top plate portion **121**B according to Pascal's law, the central part of the top plate portion **121**B coincides with a centroid of the top plate portion. That is, the central part coincides with a position at which area moments are balanced.

4. Main Tank Unit

As shown in FIG. **4**A, the main tank unit **130** is constituted by a plurality of ink cartridges **131** each functioning as a main tank and each storing the ink which is to be supplied to a corresponding one of the sub tanks **121**, a cartridge casing **132** on which the ink cartridges **131** are removably mounted, and so on.

Each ink cartridge **131** has a flat rectangular parallelepiped shape with its width being smaller than its length and depth. The ink cartridges **131** are mounted on or attached to the cartridge casing **132** in a state in which the ink cartridges **131** are arranged in a horizontal direction such that a width direction of each ink cartridge **131** substantially coincides with the horizontal direction.

5. Ink Supply Mechanisms of Station Supply Type

5-1. General Structure of Ink Supply Mechanisms of Station Supply Type

As shown in FIG. **4**A, ink supply mechanisms **140** of a station supply type respectively include sub-tank-side joint valves **150**, main-tank-side joint valves **160**, push rods **170** respectively for pushing the other ends **122**B of the respective pressing levers **122**, slide cams **180** for actuating the respective main-tank-side joint valves **160** and the respective push rods **170**, and so on.

It is noted that the sub-tank-side joint valves **150**, the main-tank-side joint valves **160**, the push rods **170**, the slide cams **180**, and so on are provided for the respective sub tanks **121**, and the ink supply mechanisms **140** including these compo-

nents have the same structure. Thus, the following description will be given, taking one of the ink supply mechanisms **140** as an example.

The sub-tank-side joint valve **150** is fixed to the main body of the recording head unit **100** and communicates with the sub tank **121**, As shown in FIG. **4**B, a valve cap **153** in which a valve opening **152** (in FIG. **5**B) is formed is fluid-tightly attached to or fitted on one end portion of a generally cylindrical valve housing **151** which is nearer to the main-tank-side joint valve **160**. The valve opening **152** is closed by a displaceable valve member **154** which is disposed in the valve housing **151**.

It is noted that the valve cap **153** of this ink-jet printer is formed of an elastic material such as an elastomer. Further, on one end portion of the valve cap **153** which is nearer to the main-tank-side joint valve **160**, there is provided a ring-shaped projecting portion **153**A which projects toward the main-tank-side joint valve **160** so as to surround the valve opening **152**.

A coil spring **155** is an elastic means that presses, in a direction in which the valve opening **152** is closed, one of opposite sides of the valve member **154** which is farther from the main-tank-side joint valve **160**. A preset load and a spring constant of the coil spring **155** are set such that a sum of a pressing force F**1** that is applied, depending on a pressure of an inside of the valve housing **151**, to the valve member **154** in a direction in which the valve member **154** is closed, and a pressing force F**2** that is applied to the valve member **154** depending on the coil spring **155** is substantially equal to or slightly larger than a pressing force F**3** that is applied, depending on an atmospheric pressure, to the valve member **154** in a direction in which the valve member **154** is opened.

In this ink-jet printer, the sub-tank-side joint valve **150** communicates with the upper end portion of the inside space of the sub tank **121**, and the recording head **110** communicates with a lower portion of the sub tank **121**.

Also, the main-tank-side joint valve **160** is connected to the sub-tank-side joint valve **150** when the ink is supplied to the sub tank **121**, so that the sub tank **121** and the ink cartridge **131** communicate with each other. It is noted that, as shown in FIG. **4**A, the main-tank-side joint valve **160** communicates with the ink cartridge **131** via an ink supply tube or pipe such as a tube **166** or a pipe.

As shown in FIG. **4**B, a valve opening **162** is formed in one end portion of a generally cylindrical valve housing **161** which is nearer to the valve cap **153**. The valve opening **162** is closed by a displaceable valve member **163** which is disposed in the valve housing **161**.

A coil spring **164** is an elastic means for applying a pressing force to the valve member **163** in a direction in which the valve opening **162** is closed. A push rod **165** projects toward the sub-tank-side joint valve **150** so as to open the valve opening **152** by pressing the valve member **154** of the sub-tank-side joint valve **150**. The push rod **165** is integral with the valve member **1637** so as to be displaced integrally with the valve member **163**.

The slide cam **180** has a cam surface **181** which contacts respective longitudinal end portions of the push rod **170** and the main-tank-side joint valve **160** (i.e., the valve housing **161**) so as to move the push rod **170** and the main-tank-side joint valve **160** in a longitudinal direction thereof (in this ink-jet printer, in the vertical direction).

In this ink-jet printer, where the push rod **170** and the main-tank-side joint valve **160** are to be moved upward, the slide cam **180** is moved toward the left side in FIG. **4**A by a driving force from a sheet-discharge roller **190** which will be described below.

On the other hand, where the push rod **170** and the main-tank-side joint valve **160** are to be moved downward, a transfer of the driving force from the sheet-discharge roller **190** is interrupted, so that the slide cam **180** is moved toward the right side in FIG. **4**A by an elastic force of a tension spring **182**.

Also, the slide cam **180** for the sub tank **121** is integral with a base plate **183**. Further, as shown in FIG. **1**, a rack gear **183**A is provided on a portion of the base plate **183** which is located nearer to the sheet-discharge roller **190**.

A gear **190**A is provided on one of longitudinal ends of the sheet-discharge roller **190**. With the gear **190**A, there is meshed a pinion gear **184** for transmitting a driving force from the gear **190**A to the rack gear **183**A (i.e., the base plate **183**). The pinion gear **184** is disposed so as to be movable between a position at which the pinion gear **184** is meshed with the rack gear **183** and a position at which the pinion gear **184** is not meshed with the rack gear **183**. The positions of the pinion gear **184** are shifted by an actuator (not shown) such as an electromagnetic solenoid.

It is noted that the sheet-discharge roller **190** is a discharging means for discharging, to a discharging opening (not shown), a sheet on which the image has been formed. The sheet is discharged between right and left frames **191**.

5-2. General Explanation of Operation of Ink Supply Mechanism

The ink supply mechanism **140** is a station-type ink supply means that connects the sub-tank-side joint valve **150** and the main-tank-side joint valve **160** to supply the ink to the sub tank **121** when the remaining amount of the ink in the sub tank **121** is equal to or smaller than the certain amount.

It is noted that, in this ink-jet printer, when a number of the ejection of the ink by the recording head **110** (including a number of the ejection for a purging operation) reaches a certain number from a time at which the ink is last supplied to the sub tank **121**, the remaining amount of the ink in the sub tank **121** is estimated to be equal to or smaller than the certain amount.

Where a controlling device (not shown) for controlling operations of the ink-jet printer judges that the remaining amount of the ink in the sub tank **121** is equal to or smaller than the certain amount, the controlling device performs an operation for moving the pinion gear **184** to the position at which the pinion gear **184** is meshed with the rack gear **183**A, to rotate the sheet-discharge roller **190**.

As a result, as shown in FIG. **5**A, the slide cam **180** is moved toward the left side in FIG. **4**A. Thus, the push rod **170** and the main-tank-side joint valve **160** are pushed by the slide cam **180**, so as to be moved upward.

As shown in FIG. **5**B, when the main-tank-side joint valve **160** is moved upward, the push rod **165** of the main-tank-side joint valve **160** pushes up the valve member **154** of the sub-tank-side joint valve **150**, thereby opening the valve opening **152**.

Simultaneously, the valve member **163** of the main-tank-side joint valve **160** is subjected to a pushing force through the push rod **165** in a direction in which the valve opening **162** is opened. Thus, the valve member **163** is displaced downward to open the valve opening **162**, so that the sub tank **121** and the ink cartridge **131** communicate with each other.

On the other hand, an end portion of the push rod **170** pushes up the other end **122**B of the pressing lever **122**. Thus, as shown in FIG. **5**A, the one end **122**A of the pressing lever **122** is moved downward, so that the sub tank **121** is contracted as if the sub tank **121** is crushed. As a result, the ink remaining in the sub tank **121** is temporarily returned to the ink cartridge **131**.

It is noted that, where the sub tank **121** is contracted before the main-tank-side joint valve **160** and the sub-tank-side joint valve **150** are connected to each other, there is a high possibility that when the main-tank-side joint valve **160** and the sub-tank-side joint valve **150** are connected to each other, the ink leaks from the main-tank-side joint valve **160** and the sub-tank-side joint valve **150**. Thus, in this ink-jet printer, a shape of the cam surface **181** and an operation of the slide cam **180** is set such that the sub tank **121** starts to be contracted after the sub-tank-side joint valve **150** and the main-tank-side joint valve **160** have been connected to each other.

Also, where a pressure for pressing the sub tank **121** is excessively high, there is a risk that a meniscus of the ink formed in an opening of each of the nozzles of the recording head **110** is broken. Thus, the shape of the cam surface **181** and a moving speed of the slide cam **180** is set such that the sub tank **121** is contracted at a pressure at which the meniscus is not broken (for example, equal to or lower than 4 kPa).

The controlling device considers that the contraction of the sub tank **121** is finished when a specific time has passed or when a total amount of the rotation of the sheet-discharge roller **190** reaches a specific total amount of the rotation from a time at which the sheet-discharge roller **190** is started to be rotated after the pinion gear **184** is moved to the position at which the pinion gear **184** is meshed with the rack gear **183**A. Then, the controlling device performs an operation for moving the pinion gear **184** to the position at which the pinion gear **184** is not meshed with the rack gear **183**A, while stopping the rotation of the sheet-discharge roller **190**.

As a result, as shown in FIG. **6**, the slide cam **180** starts to be moved toward the right side in the figure, whereby the push rod **170** is moved downward, and the sub tank **121** is extended by its restoration force. Thus, the ink in the ink cartridge **131** supplied to the sub tank **121** by being absorbed by the sub tank **121**.

Where the slide cam **180** is further moved toward the right side in the figure, as shown in FIG. **4**A, the push rod **170** is separated from the pressing lever **122**, and the sub-tank-side joint valve **150** and the main-tank-side joint valve **160** are disconnected from each other. Thus, the sub-tank-side joint valve **150** and the main-tank-side joint valve **160** are closed.

It is noted that, where the sub-tank-side joint valve **150** and the main-tank-side joint valve **160** are disconnected from each other in the state in which the push rod **170** and the pressing lever **122** contact each other, there is a high possibility that the ink leaks from the sub-tank-side joint valve **150** and the main-tank-side joint valve **160**. Thus, in this ink-jet printer, the shape of the cam surface **181** and the operation of the slide cam **180** are set such that the sub-tank-side joint valve **150** and the main-tank-side joint valve **160** are disconnected from each other after the push rod **170** is separated from the pressing lever **122**.

In this ink-jet printer, as shown in FIG. **4**A, while the image is formed, the sub-tank-side joint valve **150** and the main-tank-side joint valve **160** are disconnected from each other, whereby the sub-tank-side joint valve **150** and the main-tank-side joint valve **160** are closed. In this state, where the ink in the sub tank **121** is consumed, the pressure in the sub tank **121** is decreased because the sub tank **121** is elastically contracted. The decreased pressure (a negative pressure) in the sub tank **121** maintains the meniscus of the ink formed in the opening of each of the nozzles of the recording head **110**.

However, where a relatively large amount of the ink in the sub tank **121** is consumed and the pressure in the sub tank **121** is excessively decreased, there is a possibility that a difference between the atmospheric pressure and the pressure in the sub tank **121** is excessively large, resulting in a break of the meniscus.

However, in this ink-jet printer, the preset load and the spring constant of the coil spring **155** are set such that the sum of the pressing force F**1** that is applied, depending on the pressure of the inside of the valve housing **151**, to the valve member **154** in the direction in which the valve member **154** is closed, and the pressing force F**2** that is applied to the valve member **154** depending on the coil spring **155** is substantially equal to or slightly larger than the pressing force F**3** that is applied, depending on the atmospheric pressure, to the valve member **154** in the direction in which the valve member **154** is opened. Thus, where the pressure in the sub tank **121** is excessively decreased, the sub-tank-side joint valve **150** is opened, so that the pressure in the sub tank **121** is increased.

Where the difference between the atmospheric pressure and the pressure in the sub tank **121** is decreased to a certain magnitude of a pressure which corresponds to the pressing force of the coil spring **155**, the sub-tank-side joint valve **150** is closed, so that the pressure in the sub tank **121** is maintained at a proper pressure for maintaining the meniscus.

That is, in this ink-jet printer, the sub-tank-side joint valve **150** is mechanically and automatically controlled so as to be opened and closed such that the difference between the atmospheric pressure and the pressure in the sub tank **121** is maintained at the certain magnitude of the pressure which corresponds to the pressing force of the coil spring **155**.

6. Features of Ink-jet Printer as the Present Embodiment

If foreign materials different from the ink such as air and dusts enter into the recording head **110**, ink ejection failure occurs. To prevent this, the ink-jet printer as the present embodiment performs a positive pressure purging operation in which the sub tank **121** is contracted periodically or when commanded by a user so as to discharge, to an outside of the recording head **110**, together with the ink, the foreign materials in the recording head **110**.

To reliably discharge the foreign materials in the recording head **110**, a relatively high ink pressure (e.g., equal to or greater than about 50 kPa) needs to be generated. However, where the sub tank is deformed so as to be expanded in the direction intersecting the extension and contraction direction because of the increase of the pressure in the sub tank **121** which is caused by the increase of the ink pressure, the positive pressure purging operation cannot be performed sufficiently.

This problem can be solved if the sub tank **121** is formed of a material having a high rigidity or formed in a shape providing the high rigidity. However, the sub tank **121** thus formed is difficult to be deformed, so that a larger amount of force is required when the sub tank **121** is extended and contracted. Thus, it is not appropriate to form the sub tank **121** so as to have the high rigidity in order to solve the problem.

However, in this ink-jet printer, on the outer side of the bellows portion **121**A, there is provided the deformation restraining ring **121**E which restrains the sub tank **121** from deforming in the direction intersecting the extension and contraction direction thereof. Thus, the sub tank **121** can be restrained from deforming outwardly without being inhibited from being extended and contracted in the extension and contraction direction thereof.

Meanwhile, when the bellows portion **121**A is expanded outwardly, the smaller diameter parts thereof tend to be deformed prior to the larger diameter pas thereof. Further, where the smaller diameter parts are expanded, the positive pressure purging operation cannot be effectively performed. However, in this ink-jet printer, since the deformation

restraining ring **121**E is fitted on one of the smaller diameter parts of the bellows portion **121**A, the sub tank **121** can be effectively restrained from being deformed. Thus, the positive pressure purging operation can be effectively performed,

Also, the contacting portion **121**F has the taper shape as described above. That is, the dimension h of the contacting portion **121**F in the direction parallel to the extension and contraction direction decreases as being nearer to the bellows portion **121**A, thereby preventing that the deformation restraining ring **121**E inhibits the bellows portion **121**A from being contracted.

Meanwhile, there will be considered a case where the first ink flow hole **121**H communicating with the recording head **110** is provided in an upper portion of the sub tank **121**, and the second ink flow hole **121**J communicating with the main tank unit **130** is provided in a lower portion of the sub tank **121**. In this case, even where the sub tank **121** is contracted so as to discharge air in the sub tank **121** to the main tank unit **130**, air accumulated in an upper portion of the inside space of the sub tank **121** is supplied to the recording head **110**, and the only ink existing in a lower part of the inside space of the sub tank **121** is supplied to the main tank unit **130**. As a result, the ink ejection failure easily occurs in comparison with an ink-jet printer not having a configuration like this.

It is noted that, like the positive pressure purging operation, an operation in which the sub tank **121** is contracted in order to discharge air in the sub tank **121** to the main tank unit **130** (hereinafter, the operation will be referred to as an air discharging operation) is performed periodically or when commanded by the user.

In this ink-jet printer, as described above, the second ink flow hole **121**J and the upper end portion of the inside space of the sub tank **121** communicate with each other via the opening **121**N which is displaced downward in accordance with the contraction of the sub tank **121**. Further, the air in the sub tank **121** is always positioned in the upper portion of the inside space of the sub tank **121** irrespective of the degree of the deformation of the sub tank **121**.

Thus, in this ink-jet printer, the opening **121**N can be positioned, irrespective of the degree of the deformation of the sub tank **121**, at a part of the inside space of the sub tank **121** in which air is accumulated. Consequently, the air in the sub tank **121** can be reliably discharged to the main tank unit **130**.

Further, in this ink-jet printer, the communication tube **121**L is elastically deformed in accordance with the contraction of the sub tank **121**. Thus, the sub tank **121** can be restored to its original shape also using the elastic force (i.e., the restoration force) of the communication tube **121**L, whereby the sub tank **121** is reliably extended. That is, the top plate portion **121**B and the bottom plate portion **121**D are forced by the restoration force so as to be displaced away from each other,

Furthermore, this ink-jet printer includes the deformation guiding ribs **121**P which guide the communication tube **121**L such that the opening **121**N moves toward the central part of the top plate portion **121**B in accordance with the contraction of the sub tank **121**. Thus, when the vertical dimension of the sub tank **121** is minimized as a result of the contraction of the sub tank **121**, the communication tube **121**L can be deformed such that the opening **121**N is positioned at the central part, as seen from the upper side of the sub tank **121**, of the top plate portion **121**B. In other words, the communication tube **121**L can be deformed such that the opening **121**N is positioned at a central part, as seen from the upper side of the sub tank **121**, of the upper end portion of the inside space of the sub tank **121**.

Where the opening **121**N is positioned at the central part of the top plate portion **121**B when the vertical dimension of the sub tank **121** is minimized as a result of the contraction of the sub tank **121**, the communication tube **121**L can assist a restoration of the sub tank **121** while restraining an inclination of the sub tank **121** when the sub tank **121** is restored to its original shape. More specifically, the communication tube **121**L can assist the restoration of the sub tank **121** without inclination of the top plate portion **121**B.

Meanwhile, in this ink-jet printer, the first ink flow hole **121**H and the second ink flow hole **121**J are provided in the bottom plate portion **121**D. If the first ink flow hole **121**H and the second ink flow hole **121**J are provided in the top plate portion **121**B, it becomes difficult, when the pressing lever **122** presses the sub tank **121** (i.e., the top plate portion **121**B), that the sub tank **121** is deformed evenly in the vertical direction because the sub tank **121** is inclined due to, e.g., a presence of flexible ink tubes connected to the first ink flow hole **121**H and the second ink flow hole **121**J.

Where the sub tank **121** is not contracted evenly in the vertical direction, an actual degree of the contraction of the sub tank **121** relative to an amount of the operation of the pressing lever **122** is decreased. Thus, an efficiency of the pressing of the pressing lever **122** is lowered, thereby lowering efficiencies of respective operations such as the positive pressure purging operation, the air discharging operation, and an operation for returning the ink to the main tank unit **130**.

However, in this ink-jet printer, the first ink flow hole **121**H and the second ink flow hole **121**J are provided in the bottom plate portion **121**D on which the pressing force of the pressing lever **122** does not act directly. Thus, the sub tank **121** can be contracted evenly in the vertical direction, thereby preventing the lowering of the efficiencies of the respective operations such as the positive pressure purging operation and the operation for returning the ink to the main tank unit **130**.

7. Other Embodiments

In the above-described embodiment, as shown in FIG. **3**A, the first ink flow hole **121**H and the second ink flow hole **121**J are provided in opposite side parts of the bottom plate portion **121**D, but the ink-jet printer according to the present invention is not limited to this arrangement.

In the above-described embodiment, the bellows portion **121**A can be extended and contracted in the vertical direction, but the ink-jet printer according to the present invention is not limited to this configuration. Further, in the above-described embodiment, the communication tube **121**L can be elastically deformed, but the ink-jet printer according to the present invention is not limited to this configuration. That is, for example, the opening **121**N may be connected to the top plate portion **121**B, e.g., by modifying the communication tube **121**L to have a telescopic configuration so as to be extended and contracted in its axial direction, by pivotably attaching the communication tube **121**L to the bottom plate portion **121**D so as to pivot in the vertical direction in accordance with the vertical displacement of the top plate portion **1211**B, or by modifying the communication tube **121**L to be formed of a flexible material having little elasticity.

In the above-described embodiment, the guide for guiding the communication tube **121**L during its deformation such that the opening **121**N moves toward the central part includes the deformation guiding ribs **121**P, but the ink-jet printer according to the present invention is not limited to this configuration. That is, for example, the communication tube **121**L may be connected to the second ink flow hole **121**J in a state in which the communication tube **121**L is inclined relative to the bottom plate portion **121**D, or the top plate portion **121**B may be provided with an inclined surface for guiding,

during an initial deformation of the communication tube **121**L, a direction in which the communication tube **121**L is deformed.

In the above-described embodiment, the deformation restraining ring **121**E is provided at the position at which the bellows portion **121**A is divided into two equal parts in the vertical direction, but the ink-jet printer according to the present invention is not limited to this configuration. That is, for example, (n−1) pieces of deformation restraining rings **121**E may be fitted on the bellows portion **121**A such that the bellows portion **121**A is divided into a total number of n equal parts in the vertical direction. As another modification, the deformation restraining ring **121**E or the (n−1) pieces of deformation restraining rings **121**E may be fitted on the bellows portion such that the bellows portion **121**A is divided into unequal parts in the vertical direction, or the deformation restraining ring **121**E may not be provided, for example.

In the above-described embodiment, the sub tank **121** has the substantially rectangular shape in its cross section, but the ink-jet printer according to the present invention is not limited to the this configuration. That is, for example, the sub tank **121** may have a round shape in its cross section.

In the above-described embodiment, the deformation restraining ring **121**E is fitted on the bellows portion **121**A such that the contacting portion **121**F is fitted on the one of the smaller diameter parts, but the ink-jet printer according to the present invention is not limited to this configuration. That is, for example, the deformation restraining ring **121**E may be fitted on the bellows portion **121**A so as to cover a top part of one of the larger diameter parts.

In the above-described embodiment, the contacting portion **121**F has the taper shape, but the ink-jet printer according to the present invention is not limited to this configuration. That is, for example, the, contacting portion **121**F may have a spherical shape. Also, in the above-described embodiment, the deformation restraining ring **121**E has the generally rectangular shape having the rounded corners (i.e., a generally O-shape), but the ink-jet printer according to the present invention is not limited to this configuration. That is, for example, the deformation restraining ring **121**E may have a U-shape or a C-shape.

In the above-described embodiment, the present invention is applied to the ink-jet printer of the station supply type, but the application of the present invention is not limited to the ink-jet printer of the station supply type. Further, the present invention is not limited to the details of the illustrated embodiments, but may be embodied with various changes and modifications, which may occur to those skilled in the art, without departing from the spirit and scope of the present invention.

What is claimed is:

1. An ink-jet printer, comprising:

a recording head which ejects ink onto a recording medium;

a main tank which stores the ink to be supplied to the recording head;

a sub tank configured to be extended and contracted in a vertical direction and including first and second ink flow holes provided in a lower portion of the sub tank, such that the first ink flow hole communicates with the recording head while the second ink flow hole communicates with the main tank; and

a communication tube which is connected, at one of opposite ends thereof, to the second ink flow hole and which has, at the other of opposite ends thereof, an opening positioned in an inside space of the sub tank, whereby the second ink flow hole and the inside space of the sub tank communicate with each other via the communication tube,

wherein the communication tube is configured such that the opening of the communication tube is displaced downwardly in accordance with the contraction of the sub tank.

2. The ink-jet printer according to claim **1**,

wherein an entirety of the communication tube is in the sub tank.

3. The ink-jet printer according to claim **1**,

wherein in accordance with the extension and contraction of the sub tank, the communication tube is deformed such that the opening is displaced upwardly and downwardly.

4. The ink-jet printer according to claim **3**,

wherein the opening is positioned at an upper end portion of the inside space of the sub tank, irrespective of a degree of the extension and contraction of the sub tank.

5. The ink-jet printer according to claim **3**,

wherein the communication tube is elastically deformed in accordance with the extension and contraction of the sub tank.

6. The ink-jet printer according to claim **1**,

wherein the sub tank has an upper end wall, a lower end wall, and a peripheral wall which is provided between the upper end wall and the lower end wall and which is configured to be extended and contracted in the vertical direction,

wherein the second ink flow hole is provided in the lower end wall,

wherein the communication tube extends from the lower end wall toward the upper end wall, and

wherein the communication tube constantly contacts, at the other end thereof, the upper end wall of the sub tank, irrespective of a degree of the extension and contraction of the sub tank.

7. The ink-jet printer according to claim **6**,

wherein the communication tube is elastically bent, irrespective of the degree of the extension and contraction of the sub tank.

8. The ink-jet printer according to claim **7**,

wherein the upper and lower end walls are forced by an elastic restoration force generated by the communication tube, so as to be displaced away from each other.

9. The ink-jet printer according to claim **1**,

wherein when a vertical dimension of the sub tank is minimized as a result of the contraction of the sub tank, the opening of the communication tube is positioned at a central part, as seen from an upper side of the sub tank, of an upper end portion of the inside space of the sub tank.

10. The ink-jet printer according to claim **9**, further including a guide which guides the communication tube such that the opening moves toward the central part in accordance with the contraction of the sub tank.

11. The ink-jet printer according to claim **10**,

wherein the guide is configured to guide the communication tube in a state in which the guide engages opposite sides of the other of the opposite ends of the communication tube, the opposite sides being radially opposed to each other in a direction perpendicular to the vertical direction.

12. The ink-jet printer according to claim **10**,

wherein the guide is configured to guide the communication tube such that the opening is moved in one direction as seen from an upper side of the sub tank.

13. The ink-jet printer according to claim 10,
wherein the sub tank has an upper end wall, a lower end wall, and a peripheral wall which is provided between the upper end wall and the lower end wall and which is configured to be extended and contracted in the vertical direction,
wherein the second ink flow hole is provided in the lower end wall,
wherein the communication tube extends from the lower end wall toward the upper end wall,
wherein in a state in which the sub tank is extended, the opposite ends of the communication tube are positioned at respective positions each of which is located outside the central part of the upper end wall as seen from an upper side of the sub tank, and
wherein the communication tube is bent more strongly in accordance with the contraction of the sub tank

14. The ink-jet printer according to claim 13,
wherein the guide is provided on a lower face of the upper end wall of the sub tank such that a groove portion in which the communication tube is received is formed.

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